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Children and other high-risk workers as a special challenge to occupational health services

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The protection of children, pregnant women, and other high-risk workers poses special challenges to occupational health services. Fetuses, infants, and children have unique susceptibilities that differ qualitatively from those of adults. Evidence is accumulating that children's pre- and postnatal exposures to occupational and environmental factors are contributing to changing patterns of pediatric disease, as well as to increased risk of disease in adult life. Yet neither occupational health services nor systems for risk assessment or regulation are geared to their protection. Instead, these systems are based on the assumption that all workers are at equal risk. To protect infants and children against toxicants, fundamental revisions to current approaches are required. The central elements are (i) improved quantitative assessment of children's exposures, (ii) the development of new approaches to toxicity testing, and (iii) the application of conservative uncertainty and safety factors in risk assessment that specifically considers children's risks.

Key terms children; precautionary principle; risk assessment; special populations; toxicity testing.

Children are not little adults. Infants and children have unique patterns of exposure and developmentally determined susceptibilities that differ qualitatively from those of adults (1). Likewise, the fetus that a pregnant woman carries to work has vulnerabilities that are very different from those of an adult worker.

Evidence is accumulating that children's pre- and postnatal exposures to occupational and environmental factors are contributing to changing patterns of pediatric disease, as well as to increased risk of disease in adult life (the Barker hypothesis) (2). For these reasons, children and pregnant women require special consideration in risk assessment and in the setting of workplace exposure standards.

The International Labour Organization (ILO) estimates that there are at least 250 million working children between the ages of 5 and 14 years in developing countries. Of these, about 120 million are estimated to be working full-time, while the rest combine work with school or other activities. Most of these children live in Asia (61%), followed by Africa (32%), and Latin America and the Caribbean (7%). In the United States (US), the Department of Labor estimates that more than 4 million children are legally employed and that another 1–2 million are employed under illegal, often exploitative conditions.

Children are highly vulnerable to chemical toxins in the workplace and in the general environment due to the fact that they have exceptionally heavy exposures to environmental toxicants and unique biological vulnerabilities. Pound for pound of body weight, children drink more water, eat more food, and breathe more air than adults. In the first 6 months of life, children drink seven times as much water as the average adult. Children between 1 and 5 years of age eat three to four times that of an adult. The health implication of these findings is that children have substantially heavier exposures than adults to any toxicants that are present in water, food, or air.

Children's metabolic pathways, especially in the first months after birth, are immature. Their ability to metabolize, detoxify, and excrete many toxicants differs from that of adults. In some instances, children are better able to deal with environmental compounds, such as polyaromatic hydrocarbons and estrogen. More commonly, however, they are less able to deal with chemical

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toxins, such as lead and organophosphate pesticides, because they do not have the enzymes necessary to metabolize the toxins and thus are more vulnerable to them.

Children undergo rapid growth and development, and their developmental processes are easily disrupted. Organ systems in infants and children undergo very rapid change prenatally, as well as in the first months and years after birth. These developing systems are very delicate and are not so able to repair damage that may be caused by environmental toxicants. Thus, if chemicals such as lead, mercury, or solvents destroy cells in an infant's brain or if false signals are sent to the developing reproductive organs, the risk is high that the resulting dysfunction will be permanent and irreversible.

Because children have more future years of life than most adults, they have more time to develop chronic diseases triggered by early exposures. Many of the diseases, including cancer and neurodegenerative diseases, are now thought to arise through a series of stages that require years or even decades to evolve from the earliest initiation to the actual manifestation of disease. Carcinogenic and toxic exposures sustained in early life, including prenatal exposures, appear more likely to lead to disease than similar exposures encountered later.

Children's exposure to chemicals

At present, more than 80 000 chemicals are registered for commercial use with the US Environmental Protection Agency (EPA) and the OECD. More than 2800 of these are high-production volume chemicals produced in quantities of more than 1 million Kg per year (3). These chemicals are distributed widely in the environment—in air, food, water, and consumer products. They can enter children's bodies by ingestion, inhalation, or transdermal absorption. Of great concern is the fact that only 43% of these chemicals have been even minimally tested for their potential to cause toxicity, and fewer than 20% have been examined for their capacity to interfere with fetal and children's development. A full set of toxicity information is publicly available for only 7% of such chemicals (4).

Changing patterns of disease

The major diseases confronting children in industrially developed nations today are the chronic illnesses of multifactorial origin—asthma, which has doubled in frequency since 1980; birth defects, which remain the leading cause of infant death; developmental disorders, such as hyperactivity disorder and autism; acute lymphocytic leukemia, whose incidence increased by 61.7% from 1973 to 1999 (5); and primary brain cancer, whose incidence increased among children in the USA by 39.6% from 1973 to 1994 (6); similar increases occurred in Western Europe during this time. Although genetic factors may account for 10% to 20% of cases of chronic disease in childhood, most of the causes of these diseases are unknown.

It is strongly suspected that some pediatric diseases are caused at least in part by exposures to environmental toxins. Working women in the United States are legally allowed a blood lead level of 40 μg/dl. This is especially problematic for women who are either pregnant or reproductively active. The placenta is not an absolute barrier to the environmental toxins known to cause neurodevelopmental disorders, such as thalidomide, diethyl stilbestrol (DES), lead, methyl mercury, polychorinated biphenyls (PCBs), ethyl alcohol, and others. For instance, lead easily crosses the placenta and causes fetal brain injury at blood lead levels of <10 μg/dl. The blood–brain barrier, which insulates the brain from toxins in the bloodstream, is not fully developed until the first year of life. Yet neither occupational health services nor systems for risk assessment or regulation are geared to the protection of high-risk populations. These systems are based on the notion that all workers are at equal risk and that one set of standards will protect all workers.

Subclinical toxicity

A critically important intellectual step in the development of understanding children's special vulnerability was the recognition that environmental toxins can exert a range of adverse effects in children (7). Some of these effects are clinically evident, but others can be discerned only through special testing and are not evident in standard examinations, hence the term "subclinical toxicity". The underlying concept is that a dose-dependent continuum of toxic effects exists, in which clinically obvious effects have their subclinical counterparts. When no data are available on pediatric toxicity, an additional mandated safety factor should be imposed in risk assessment.

The concept of subclinical toxicity traces its origins to pioneering studies of lead toxicity in clinically asymptomatic children undertaken by Herbert Needleman and his colleagues. Needleman et al (8) showed that children's exposure to lead could cause decreases in intelligence and alter behavior even in the absence of clinically visible symptoms of lead toxicity. The subclinical toxicity of lead in children has subsequently been confirmed in prospective epidemiologic studies.

Similar subclinical neurotoxic effects have been documented for children exposed in utero to PCBs and methyl mercury. Widespread subclinical neurotoxicity can affect the health, well-being, and intelligence of an entire nation.

Changing policies

To protect infants and children against toxicants, in 1993, the US National Research Council called for the development of a new approach to risk assessment and regulation that is based on the presumption that children's unique patterns of exposure and special vulnerabilities place them at higher risk than adults. This approach was codified into environmental law in the United States with the passage of the Food Quality Protection Act in 1996 (9), the major federal statute in the US governing pesticide exposure standards. It needs now to be extended to the workplace. The central elements are (i) improved quantitative assessment of children's exposures at different stages in life, from fetal life through adolescence, including exposures to multiple agents; (ii) the development of new approaches to the toxicity testing of chemicals that can detect unanticipated and subtle outcomes of early exposures and that evaluate experimental subjects over their entire lives; (iii) the development of new toxicodynamic and toxicokinetic models that account for the unique physiological characteristics of infants and children; (iv) the development of new approaches to the assessment of functional outcomes; and (v) the application of conservative uncertainty and safety factors in risk assessment that specifically consider children's risks. Clinical services staffed jointly by pediatricians and occupational health physicians are increasingly needed for exposed children and have been established in the United States, Mexico, Canada, and Spain.

A primary need for the prevention of disease that may be caused or triggered by chemicals among children is to strengthen legal requirements for toxicity testing. The current federal law in the United States that is intended to mandate such testing, the Toxic Substances Control Act, remains largely unenforced. The REACH program for chemical safety that has been proposed for the European Union appears much stronger. Legislative and regulatory mechanisms requiring the premarket testing of new chemicals and postmarket monitoring of the chemicals, together with postmarket testing and monitoring of current chemicals, are essential for the adequate protection of children. Such testing must include developmental neurotoxicologic testing and cancer testing of all chemicals.

Concluding remarks

The protection of children against environmental toxins is a major challenge to modern society. Hundreds of new chemicals are developed every year and are released into the environment. Most of these chemicals are untested for their toxic effects on children. The challenge is to design policies that specifically protect children against environmental toxins. To meet this challenge, a new paradigm for environmental health policy needs to be developed that is centered on the sensitivities and exposures of children. The analysis begins with the child, his or her biology, exposure patterns, and developmental stage (11). The paradigm calls for a new way of thinking and a re-tooling of the risk assessment process so that it takes into account the increased vulnerability of children that embodies the Precautionary Principle (12). As we begin the 21st century, the issue of environmental exposure looms large globally. It is imperative that we develop prudent policies that will protect the health of our children now and in the future.

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